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Kit fox © 1987 Susan Middleton

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TRACE METAL CONCENTRATIONS IN SAN JOAQUIN KIT FOXES FROM THE SOUTHERN SAN JOAQUIN VALLEY OF CALIFORNIA

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We measured kidney concentrations of zinc (Zn), copper (Cu), cadmium (Cd), lead (Pb), nickel (Ni), chromium (Cr), and molybdenum (Mo) in radio-collared San Joaquin kit foxes, *Vulpes macrotis mutica*, that died between 1991 and 1993. We compared results for kit foxes inhabiting an oil field with kit foxes inhabiting an undeveloped reference site. Concentrations of Zn, Cu, Cd, Pb, Ni, Cr, and Mo in kit fox kidneys were either below detectable levels or were within ranges reported for other mammals from unpolluted sites. Concentrations of Zn, Cu, and Cd tended to be higher in foxes from the oil field, although these differences were not significant.

INTRODUCTION

The San Joaquin kit fox, *Vulpes macrotis mutica*, is a federally designated endangered species found primarily in the southern San Joaquin Valley of California. Loss of habitat to agricultural, urban, and industrial development has contributed to its endangered status. However, unlike intensive agricultural or urban developments, areas of petroleum development often retain enough suitable habitat to support kit fox populations (CEC[2] 1996). Several petroleum production areas have been identified as important kit fox habitat and evaluating the effects of toxins on kit foxes has been

[1] Present address: 8352 McCourtney Road, Lincoln, California 95648

[2] CEC. 1996. Studies of the San Joaquin kit fox in undeveloped and oil-developed areas. California Energy Commission, Sacramento, California, USA.

identified as a research goal for San Joaquin kit fox recovery (USFWS[3] 1989).

Several potentially toxic metals are associated with petroleum production. The metals most commonly encountered in oil fields are arsenic, chromium, copper, lead, lithium, molybdenum, nickel, and vanadium (Edwards and Gregory 1991, Peakall et al. 1982). Nickel and vanadium are found in crude oil while the others are components of materials used in the petroleum production process (Seiler et al. 1988).

Mortality due to metal toxicity has been reported in livestock kept in oil fields (Kerr and Edwards 1981). Elevated zinc, copper, and cadmium concentrations have been detected in muskrat tissues collected from sites receiving industrial and mining waste (Everett and Anthony 1976). Blus et al. (1987) found elevated concentrations of metals in the tissues of animals collected at mining sites in Idaho and attributed population declines to the effects of the metal pollution.

Concentrations of arsenic, barium, iodine, uranium, and vanadium were elevated in the hair of kit foxes inhabiting an oil field near our study sites (Suter et al.[4] 1992). Although evaluation of metal concentrations in hair has been suggested as a means of monitoring environmental contamination (Jenkins[5] 1981), this approach is controversial (Chatt and Katz 1988). Metal concentrations in internal organs are considered more reflective of true body burden and potential toxicity than concentrations in hair. We conducted this study to describe concentrations of zinc (Zn), copper (Cu), cadmium (Cd), lead (Pb), nickel (Ni), chromium (Cr), and molybdenum (Mo) in kit fox kidney tissue in animals inhabiting an oil field, and compare these findings to levels in foxes from an unpolluted reference site.

METHODS

The Midway-Sunset oil field is located approximately 9 km north of Taft, Kern County, California (35°08'N, 119°27'W). Surface disturbance (oil pump platforms, power generation facilities, pipe and steam lines, graded areas and cut banks, and other oil-related structures and roads) of the approximately 20 km^2 study area is greater than 70%. Average oil pump density is 243/km^2. The undeveloped reference area is approximately 32 km^2 and located in the Lokern Natural Area, approximately 5 km east of Buttonwillow, Kern County, California (35°24'N, 119°28'W). Surface disturbance is limited to unpaved, infrequently used roads and the California Aqueduct along the northern border. Vegetation at both sites consists mainly of saltbush scrub, *Atriplex* spp., and non-native annual grasses, *Bromus* spp. (CEC[2] 1996).

Kidneys were collected at necropsy from radio-collared adult kit foxes that died

[3] USFWS. 1989. San Joaquin kit fox recovery plan. United States Fish and Wildlife Service, Portland, Oregon, USA.

[4] Suter, G.W., A.E. Rosen, J.J. Beauchamp, and T.T. Kato. 1992. Results of analyses of fur samples from the San Joaquin kit fox and associated soil and water samples from the Naval Petroleum Reserves No. 1, Tupman, California. ORNL/TM 12244. Oak Ridge National Laboratory, Oak Ridge, Tennessee, USA.

[5] Jenkins, D.W. 1981. Biological monitoring of toxic trace elements. EPA-600/S3-80-090. United States Environmental Protection Agency, Las Vegas, Nevada, USA.

during 1991–1993. Samples were obtained from 10 foxes (3 males, 7 females) from the oil field and from 9 foxes (4 males, 5 females) from the reference area. Tissue samples were in various states of decomposition and only kidneys with an intact capsule and firm parenchyma were used. One kidney from each fox was placed in a polyethylene bag and stored at −12° C until prepared for analysis. After thawing, capsules were removed and each kidney was finely chopped, lyophilized overnight, and submitted to the Division of Agriculture and Natural Resources Analytical Laboratory (DANR-AL) at the University of California, Davis for analysis.

At DANR-AL, samples were prepared by microdigestion with nitric acid and hydrogen peroxide using a microwave digestion protocol as described by Sah and Miller (1992). Concentrations of Zn, Cu, Cd, Pb, Ni, Cr, and Mo were determined with an inductively coupled plasma atomic emission spectrometer fitted with an ultrasonic nebulizer.

Concentrations were reported on a dry-weight basis. Samples with concentrations below the detection limit of 0.05 ppm were assigned a value of 0.025 ppm for statistical analysis (Helsel 1990). Data were analyzed using the Mann-Whitney-U test (Zar 1984). Values greater than 3 standard deviations from the mean were considered outliers and were omitted from statistical analysis. In recognition of the low potential power associated with our small sample sizes, P-values ≤ 0.10 were considered significant.

RESULTS

A single fox from the reference area had extremely high concentrations of Zn (910 ppm) and Cu (60.4 ppm) in its kidney tissue. In contrast, Zn and Cu concentrations in all other foxes examined ranged from 64 to 108 ppm and 10.6 to 22.1 ppm, respectively. No obvious explanation for this finding was apparent. Markedly elevated Zn and Cu levels have been reported in animals that have ingested copper-coated zinc pennies minted after 1982 (Meurs et al. 1991, Agnew et al. 1999). It was not determined whether this fox had ingested a penny as no radiographs were taken and stomach contents were not examined. The Zn and Cu concentrations in this fox were considered outliers (based on the criterion in Methods) and were not included in the statistical analyses of Zn and Cu concentrations.

Mean concentrations of Zn, Cu, and Cd tended to be higher in foxes collected in the oil field, although none of these differences were statistically significant ($P > 0.10$). Concentrations of Pb, Ni, Cr, and Mo were below detectable levels (<0.05 ppm) for all foxes examined (Table 1). Concentrations of Cd were below detectable levels (<0.05 ppm) in 4/10 foxes from the oil field and 5/9 foxes from the reference area.

Zinc concentrations ranged from 68 to 108 ppm in foxes collected in the oil field and from 64 to 91 ppm in foxes from the reference area. Copper concentrations ranged from 14.5 to 20.8 ppm in foxes collected in the oil field and from 10.6 to 22.1 ppm in foxes from the reference area. Cadmium concentrations ranged from <0.05 to 0.46 ppm in foxes from the oil field and from <0.05 to 0.19 ppm in foxes from the reference area.

Table 1. Mean metal concentrations in kit foxes from the southern San Joaquin Valley and in animals from unpolluted control sites.[a] Sample sizes are in parentheses. NR = not reported.

Species	Tissue	Zn	Cu	Cd	Pb	Ni	Cr	Mo	Reference
Kit fox Reference site (9)[b]	Kidney	75.8	16.5	0.07	<0.05	<0.05	<0.05	<0.05	This study
Kit fox Oil field (10)[b]	Kidney	80.3	17.3	0.10	<0.05	<0.05	<0.05	<0.05	This study
Meadow vole (3)	Kidney	80	≤28	NR	≤2	≤10	NR	NR	Cloutier et al. 1985
White-footed Mouse (9)	Carcass	145	8.3	1.2	7.4	NR	NR	NR	Beyer et al. 1985
Short-tailed Shrew (13)	Carcass	201	11	4.8	18	NR	NR	NR	Beyer et al. 1985
Mink (8)	Liver Kidney	40[c]	9[c]	0.20[d]	0.14[c]	NR	NR	NR	Blus et al. 1987
Cattle, sheep, Pigs (>100)	Kidney	≤302	≤42	≤4.42	≤8	NR	NR	NR	Doyle and Spaulding 1978

[a]Reported in ppm, dry weight basis assuming a moisture content of 70%

[b]Differences not statistically significant ($P > 0.10$)

[c] Zn, Cu, and Pb from liver

[d] Cd from kidney

DISCUSSION

No significant differences were detected between kidney concentrations of Zn, Cu, and Cd in foxes inhabiting the oil field and foxes inhabiting the undeveloped reference area. However, the power of our statistical tests to detect differences between means for Zn, Cu, and Cd was low (≤0.23). Therefore, even if the 2 populations did differ with respect to tissue metal concentrations, it is unlikely that we could detect it statistically due to our small sample sizes.

Although not statistically significant, mean concentrations and ranges of Zn, Cu, and Cd tended to be higher in foxes inhabiting the oil field. All 3 of these metals, particularly Cu and Cd, have widespread uses in industry (Seiler et al. 1988) and the higher concentrations found in the oil field may be attributable to oil field-related pollution. Alternatively, higher concentrations of these metals may reflect differences in soil composition or other non-industrial environmental factors.

Suter et al.[4] (1992) found hair concentrations of Zn to be higher in kit foxes from

oil fields than in foxes from undeveloped areas. However, they suggested that this was probably attributable to causes other than exposure to oil field materials, as Zn is not usually associated with petroleum production. Seiler et al. (1988) reported that Zn content of soil is generally higher near industry or highways due to emissions and particles associated with tire wear. This may account for findings of higher Zn concentrations in foxes inhabiting oil fields as more vehicular and large machinery traffic occurs in oil fields than in undeveloped areas. Hair concentrations of Cu and Cd did not appear to be related to oil field production in the same study (Suter et al.[4] 1992).

Mean kidney concentrations of Zn, Cu, and Cd for both kit fox populations we sampled were within normal ranges reported for domestic livestock (Doyle and Spaulding 1978). Mean concentrations of Zn and Cu were within the ranges of means reported for meadow voles, *Microtus pennsylvanicus*; white-footed mice, *Peromyscus leucopus*; short-tailed shrews, *Blarina brevicauda*; and mink, *Mustela vison*, from uncontaminated sites in North America. Mean Cd concentration in kit fox kidney tissue was lower than means reported for the above species (Cloutier et al. 1985, Beyer et al. 1985, Blus et al. 1987).

Concentrations of Pb, Ni, Cr, and Mo in kidney tissue were below detectable levels for all foxes. Levels of Pb and Ni in kit fox hair did not appear to be associated with petroleum production in an oil field near the present study sites, although Cr and Mo concentrations in fur did appear to be related to exposure to oil field development (Suter et al.[4] 1992).

ACKNOWLEDGMENTS

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ASSOCIATION OF FALL-RUN CHINOOK SALMON REDDS WITH WOODY DEBRIS IN THE LOWER MOKELUMNE RIVER, CALIFORNIA

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Surveys in the lower Mokelumne River during 1994–1995 indicated that fall-run chinook salmon, *Oncorhynchus tshawytscha*, redds associated with woody debris (WD) had smaller substrate and greater mean depths. Also, the proportion of redds associated with WD was negatively related to stream gradient. Female chinook salmon selected spawning sites containing WD in some instances. Woody debris may make less desirable habitats more suitable for spawning and may allow greater concentrations of redds on suitable sites.

INTRODUCTION

Over the past 2 centuries, human activity has greatly altered the inland waterways of the Pacific West. Development on aquatic systems and excessive harvest of natural resources, including gravel, timber, and fish, have depleted native salmonids. Habitat condition is a key factor regulating salmonid production and can limit the carrying capacity of these streams for fish (House and Boehne 1985). Thus, management programs are aimed at increasing naturally spawning wild stocks through rehabilitation of severely altered habitats.

The presence of woody debris (WD) in streams is a potential source of log jams that could block river flow, impede navigation, reduce flood-control capacity, destabilize levees, and impair passage of migrating adult salmonids. As a consequence of these concerns, many maintenance programs are aimed at the removal of WD from stream channels, even though WD may play an important role in the creation and maintenance of fish habitat throughout entire river systems (Bisson et al. 1987).

Few studies have explored the importance of WD to spawning salmonids, although the influences of instream structure on juvenile salmonids has been extensively discussed in the literature (Ward and Slaney[1] 1979, Ward and Slaney 1981, House and Boehne 1985, Fuller 1990). Woody debris is also an important energy source for benthic invertebrates (Anderson et al. 1978, Bisson et al. 1987), a principal food of juvenile salmonids (Mundie 1974). Woody debris provides cover for adult

[1] Ward, B.R. and P.A. Slaney. 1979. Evaluation of instream enhancement structures for the production of juvenile steelhead trout and coho salmon in the Keogh River: Progress 1977 and 1978. Fisheries Technical Circular 45, Ministry of the Environment, Fish and Wildlife Branch, Vancouver, British Columbia, Canada.

salmonids (Bjornn and Reiser 1991), and low gradient sediment deposits upstream of debris accumulation can provide suitable spawning substrate in sediment-poor drainages (Everest and Meehan 1981). Woody debris may create scour pools with tail-outs appropriate for redd construction in sediment-rich streams (Sedell et al. 1982). House and Boehne (1985) described the accumulation of superior salmon spawning material near gabion structures placed in East Fork Lobster Creek, Oregon to mimic large debris. House and Crispin (1990) evaluated the economic value of large WD in salmonid habitat, but only estimated numbers of adult salmonids from sampled juvenile populations.

Heavily wooded streams of the Pacific West have supported genetically and morphologically distinct strains of salmonids (Beacham and Murray 1987, Beacham et al. 1988). The amount and size of woody material that each forest contributes to stream habitats is directly linked to the vegetative composition of the riparian zone and, as some streams may lack the woody structure present in the old growth watersheds, they may also lack habitat structure for fish (Flebbe and Dolloff 1995).

The purpose of this study was to examine the association of fall-run chinook salmon, *Oncorhynchus tshawytscha,* redds with WD in the lower Mokelumne River below Camanche Dam. Specifically, I evaluated the association between WD and depth, stream velocity, gradient, and occurrence of salmon redds.

STUDY AREA

The lower Mokelumne River below Camanche Dam is characterized by alternating bar-complex and flatwater habitats, with a gradient of approximately 0.17 m/km. The drainage area below Camanche Dam consists of 87 km^2 of mostly agricultural and urbanized land (Fig. 1) (USGS 1977). Two reservoirs, Pardee and Camanche, are located 77 and 59 km upstream from the extension of tidewater influence. In 1964, the Mokelumne River Fish Hatchery was constructed at the base of Camanche Dam to mitigate loss of chinook spawning habitat above the dam. Lake Lodi, a 191.7-hectare reservoir, is formed by Woodbridge Dam, 40 km downstream from the hatchery. A fish ladder allows adult salmonids to pass above Woodbridge Dam to the section of river from Lake Lodi to Camanche Dam. Annual monitoring of adult chinook salmon passing Woodbridge Dam is conducted by trapping and video monitoring in the ladder from 1 October through 31 December (Marine and Vogel[2] 1996).

Annual chinook salmon redd surveys are also conducted from 1 October through 31 December (Hartwell[3] 1995). Primary spawning habitat is located in the 8-km river reach downstream from Camanche Dam to the town of Clements (Fig. 1). Riffles

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[2] Marine, K.R. and D.A. Vogel. 1996. Mokelumne River chinook salmon and steelhead monitoring program, 1994–1995. Natural Resource Scientists, Inc., Red Bluff, California, USA.

[3] Hartwell, R. 1995. Upstream migration and spawning of fall run chinook salmon in the Mokelumne River, 1994. East Bay Municipal Utility District, Orinda, California, USA.

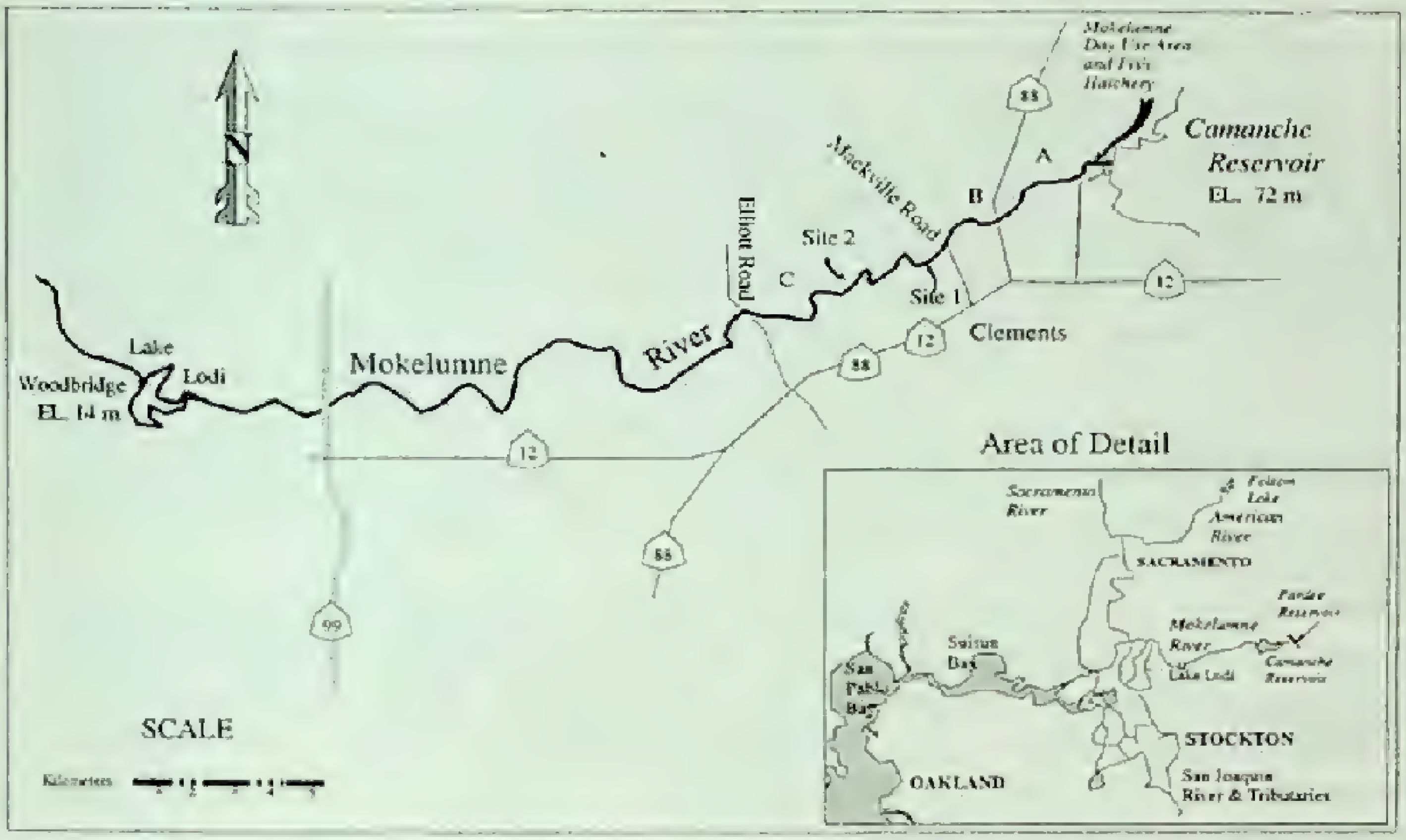

Figure 1. The lower Mokelumne River between Camanche and Woodbridge dams, San Joaquin County, California, showing chinook salmon redd sampling sections (A, B, C) and sites (1, 2).

and pools in this area are bordered by alternating strips of white alder, *Alnus rhombifolia*; Fremont cottonwood, *Populus fremontii*; valley oak, *Quercus lobata*; and sandbar willow, *Salix exigua*. Downstream of Clements, the river becomes a narrow, meandering stream confined by sparsely vegetated levees along both banks with few spawning riffles of poor quality.

Average water release from Camanche Dam during the 1994–1995 spawning season was 6.8 m^3/s. From 7 October to 31 December 1994, 3,221 adult chinook salmon were counted by trapping and video monitoring at the Woodbridge Dam fish ladder (Hartwell[3] 1995). The Mokelumne River Fish Hatchery recorded 1,920 adult salmon returning to the hatchery during the 1994–1995 season (Hartwell[3] 1995).

METHODS

The river was separated into 3 sections: Section A, the base of Camanche Dam to Highway 88; Section B, Highway 88 to Mackville Road; and Section C, Mackville Road to Elliott Road (Fig. 1). Chinook salmon redds were observed weekly by canoe and wading from Camanche Dam to Elliott Road from 25 October 1994 to 31 January 1995. Individual redds were marked by a numbered brick placed on the tail-spill of each identified redd. River flow, redd superimposition, presence or absence of gravel berms (naturally formed gravel ridges [see Huntington[4] 1985, Shirvell 1989,

[4] Huntington, C.W. 1985. Deschutes River spawning gravel study, volume I. Final Report. Project No. 83-423, Bonneville Power Administration, Portland, Oregon, USA.

Ferren et al.[5] 1996]) and association with WD was noted for each redd. Habitat units were identified and assigned to 1 of 4 habitats (modified from Bisson et al. 1981): pools (unbroken surface, slow velocity, deep water), glides (moderately shallow water with an even flow that lacked pronounced turbulence), runs (rippled surface, fast velocity, shallow water), and riffles (stream bed substrate protruding through water surface). Depth at the upstream edge of the redd (redd depth), water velocity at 6 cm above the upstream edge of the redd (nose velocity), stream velocity (average of 20% and 80% of depth below surface), and dominant substrate types were recorded. Dominant substrates were divided into 5 classes: 1) small gravel (4–32 mm), 2) medium gravel (33–50 mm), 3) large gravel (51–64 mm), 4) small cobble (65–130 mm), and 5) medium cobble (131–250 mm) (modified from Bovee and Milhous 1978).

For purposes of this study, any vegetative material with diameter >5 cm and length >30 cm was characterized as WD. This was the minimum size visible from aerial photographs. Any redd constructed in a site where its shape, depth, view from terrestrial predators, or associated turbulence was altered by the debris was considered associated with WD. Two or more observers were needed to arrive at the same conclusion to make this assessment.

Two sites (Site 1: 1,377m^2, Site 2: 1,044m^2) were used to evaluate specific location of WD and chinook salmon redds. These sites were selected based on their accessibility to foot surveys and aerial photography and consisted primarily of run and glide habitat. Both sites, located in Section C (Fig. 1), were mapped by aerial photography and ground crews. Woody debris and redds were noted for each site. Because the average area of a chinook salmon redd is approximately 9 m^2 (Bjornn and Reiser 1991, Hartwell[3] 1995), the sites were separated into grids of 9-m^2 squares. Each square was categorized as containing 1 or more redds within its boundaries and containing WD within its boundaries. If a redd was located in more than 1 square, it was counted in the square that contained the majority of the redd.

I used chi-square analysis to assess the relationship between 1) proportion of redds associated with WD and berms, 2) WD association and redd substrate size, 3) WD association and habitat types, and 4) the frequencies of redds and WD at Sites 1 and 2 (Zar 1974). I used simple linear regression to assess the relationship between 1) the proportion of redds associated with WD and average gradient in each reach and 2) proportion of newly constructed redds associated with WD and average weekly discharge from Camanche Dam (Gardner et al.[6] 1995). I also used Student's t to assess the relationship between redd association with WD and 1) redd nose velocity, 2) stream velocity, and 3) redd depth.

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[5] Ferren, W.R., P.L. Fiedler, and R.A. Leidy. 1996. Wetlands of the central and southern California coast and coastal watersheds. A methodology for their classification and description. Final report prepared for U.S. Environmental Protection Agency, Region IX, San Francisco, California, USA.

[6] Gardner, R.S., W.T. Harris, J. Weber, and R.E. Stein. 1995. East Bay Municipal Utility District Water Supply Section statistical report, fiscal year ending June 30, 1995. East Bay Municipal Utility District, Oakland, California, USA.

RESULTS

Of the 773 chinook salmon redds observed in the 3 sections, 223 (29%) were associated with WD. The proportion of redds associated with WD was negatively related to stream gradient ($F = 446.2$; df = 1, 1; $P = 0.03$) (Fig. 2). The proportion of redds associated with WD that were constructed on berms was not significantly different from those away from berms ($\chi^2 = 0.70$, df = 1, $P > 0.50$). A significant difference was observed in the proportion of redds associated with WD in different habitat types ($\chi^2 = 7.89$, df = 2, $P = 0.02$) (Table 1).

At both Sites 1 and 2, a disproportionate number of redds was associated with WD ($\chi^2 = 14.5$, df = 1, $P = 0.0001$; $\chi^2 = 10.8$, df = 1, $P = 0.001$). At Site 1 (43 redds) (Fig. 3), 44% of the plots with WD contained redds, whereas only 25% of the total plots contained redds. At Site 2 (40 redds) (Fig. 4), 60% of the plots with WD contained redds, but only 29% of the total plots contained redds.

Approximately 2 weeks into the study, a large cottonwood snag floated into Site 2, settling across the 1st berm and spanning over 50% of the channel. Undercutting

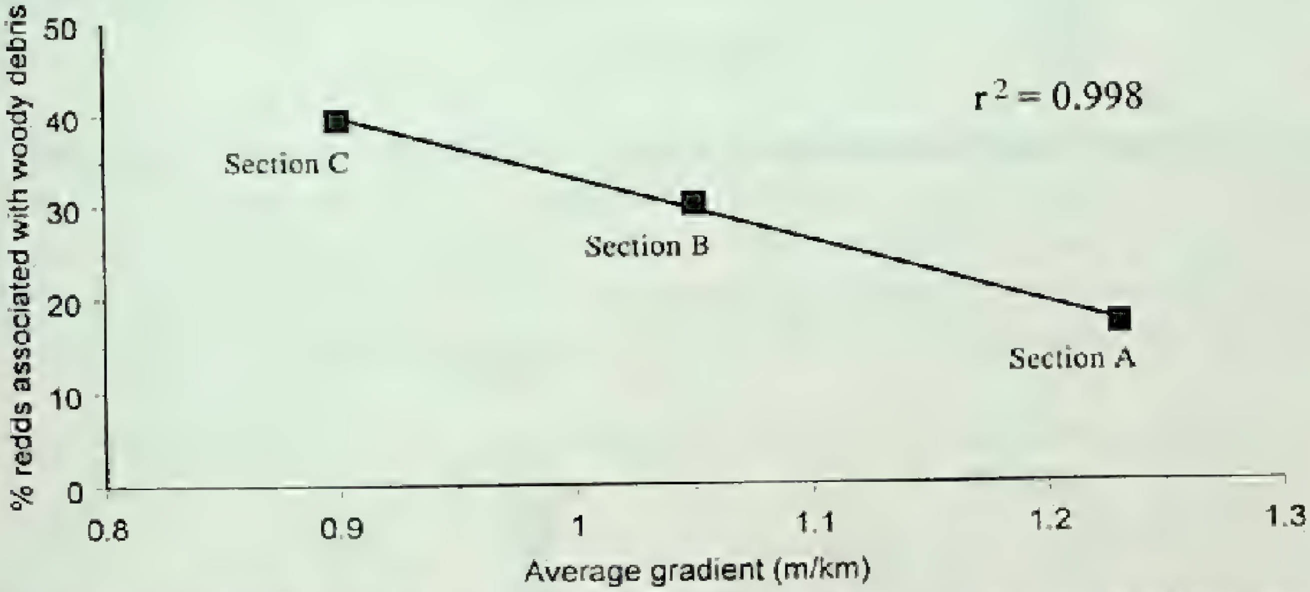

Figure 2. The relationship between percentage of chinook salmon redds associated with woody debris and mean river gradient at each section sampled on the lower Mokelumne River during the 1994–1995 spawning season.

Table 1. The association of chinook salmon redds with woody debris (WD) and several habitat variables in the lower Mokelumne River during the 1994–1995 spawning season.

Habitat Type	Redds associated with WD	Redds not associated with WD
Glide	105 (34%)	200 (66%)
Pools	No redds	No redds
Riffle	97 (25%)	295 (75%)
Run	21 (28%)	55 (72%)
On Berm	40 (26%)	115 (74%)
Off Berm	183 (30%)	435 (70%)

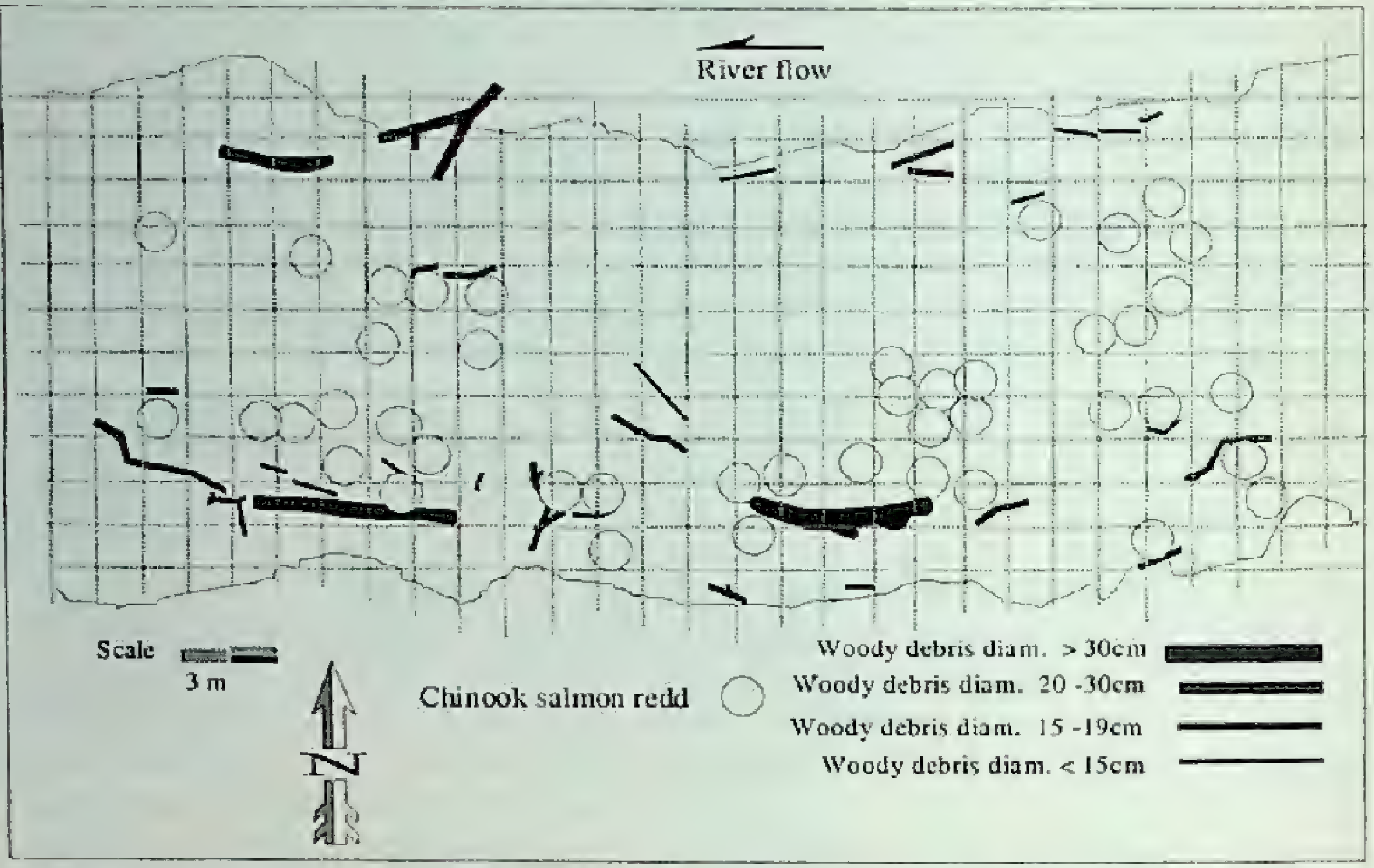

Figure 3. Location of chinook salmon redds and woody debris at Site 1, lower Mokelumne River, 1995.

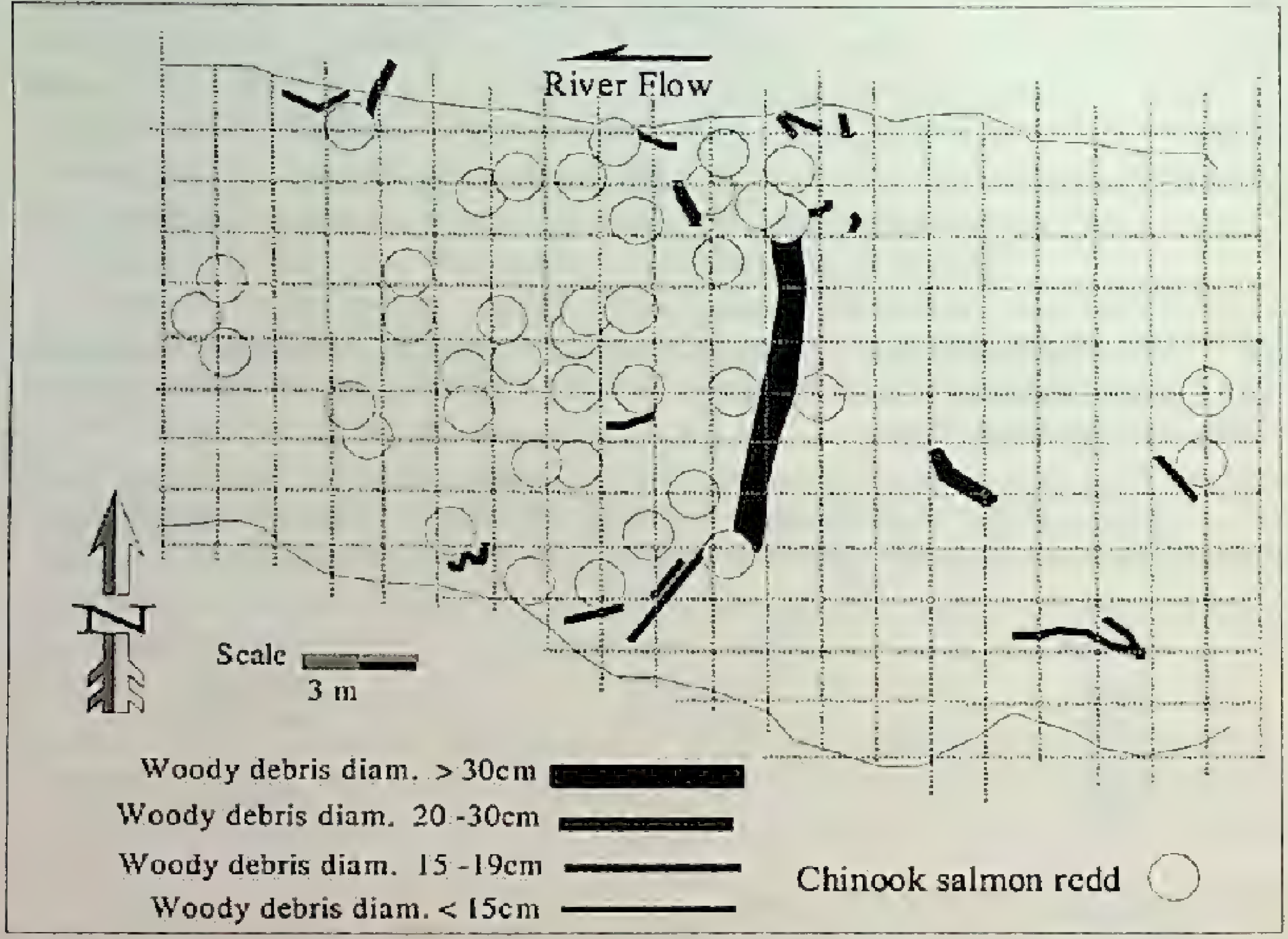

Figure 4. Location of chinook salmon redds and woody debris at Site 2, lower Mokelumne River, 1995.

occurred at this site, damaging or destroying 2 of the earliest redds. However, several other redds were constructed in front and in the 2 channels formed on either side of the snag.

Flows from Camanche Dam were gradually increased from approximately 5.7 m^3/s during the 1st week of sampling to approximately 6.8 m^3/s by the 3rd week. The proportion of newly constructed redds associated with WD was not related to mean weekly river flow ($F = 0.95$; df = 1, 8; $P = 0.36$). However, the percent of redds associated with WD peaked twice during the spawning season. These peaks appeared to lag 1 week behind peaks of weekly precipitation in the lower watershed (Fig. 5). A relationship was observed between weekly precipitation and the following week's proportion of redds associated with WD ($F = 10.82$; df = 1, 9; $P < 0.01$).

Mean depth of redds associated with WD (0.55 m) was significantly greater than for those not associated with WD (0.48 m) ($t = 2.10$, df = 87, $P = 0.04$). Stream or nose velocities were not significantly different at redd sites with and without WD ($t = 0.42$, df = 155, $P = 0.68$; $t = 0.10$, df = 156, $P = 0.92$).

Mean substrate size for redds associated with WD (50 mm) was significantly smaller than for redds not associated with WD (89 mm) ($t = 2.34$, df = 169, $P = 0.02$).

DISCUSSION

According to Bisson et al. (1987), when input of debris is from bank undercutting of living trees or the direct fall of dead trees, the debris tends to be spaced at fairly random intervals along small channels where flow is insufficient to carry the debris downstream. However, in most streams with strong flows, there is some degree of clumping and the magnitude and spacing of debris clumps generally increase in a

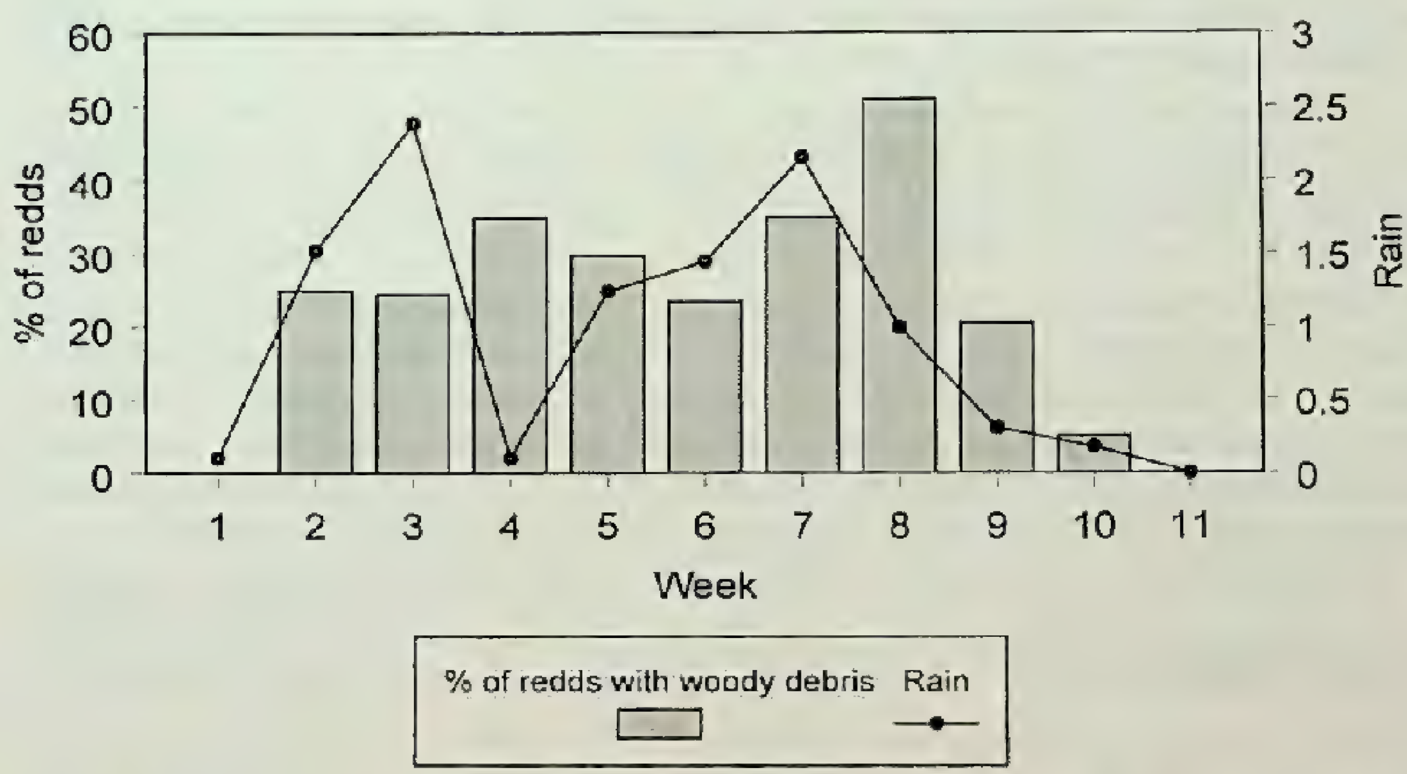

Figure 5. Comparison of the percent of chinook salmon redds associated with woody debris and weekly precipitation in the lower Mokelumne River Drainage, 25 October 1994–20 January 1995.

downstream direction. Other natural phenomena, such as beaver activity, can also affect this clumping. Previous studies indicate sediment deposits formed adjacent to WD provide suitable spawning substrate in sediment-poor drainages (Everest and Meehan 1981, House and Boehne 1985). The Mokelumne River data suggest that WD collects smaller gravel in deeper sections of the river as well. This may explain the increased association of redds with WD in a downstream direction (Fig. 2) and the disproportionate number of redds associated with WD in glide habitat (Table 1). Therefore, this clumping may be beneficial for spawning in less desirable habitats with slower, deeper water and small or fine substrate.

Whereas an increase in redd association with WD downstream may be a result of the increased amount of debris accumulation in the lower sections, selection by chinook salmon for specific sites containing WD was observed. The lack of difference between the proportion of redds associated with WD on berms and the proportion not on berms suggests that site selection is not a result of WD merely collecting at suitable sites.

During spawning, male and female chinook salmon aggressively defend the redd area (Barnhart 1986). Dolloff[7] (1983) suggested that visual isolation provided by the matrix of a root system reduces the frequency of aggressive encounters in other species of Pacific salmon. In the lower Mokelumne River, several instances were observed where thin branches 13–25 cm diameter were all that separated 2 female salmon simultaneously constructing redds. Furthermore, 4 females constructed redds simultaneously around a large piece of WD (>30 cm diameter) after it floated into Site 2 (Fig. 4). This debris appeared to provide visual segregation of spawning fish, although 2 of these redds, no longer occupied by the adults, were later re-used by other females. These observations suggest that WD may also be a factor in reducing aggressive behavior among spawning adults, allowing higher concentrations of redds on suitable sites.

While speculative, several other aspects of WD may also be attractive to spawning chinook salmon. In order for water to move around a large object, its velocity must increase. The water then slows after it passes the object and forms a back-eddy. This may be appealing to adult chinook salmon in several ways. First, increase in flow immediately adjacent to the structure may provide suitable velocities for spawning that otherwise would not be present. Second, decreased flows behind the structure may provide suitable resting habitat immediately adjacent to the redd. Third, large debris may provide cover in the form of turbulence produced by these structures (Bauer and Burton 1993). Last, this turbulence may provide increased oxygen for spawning adults and may increase intergravel water exchange through redds.

Woody debris may have an effect on the size, shape, depth, and distance between redds. On several occasions, I observed female chinook salmon constructing redds in, around, and adjacent to WD, creating redds that took on the shape and length of

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[7] Dolloff, C.A. 1983. The relationships of wood debris to juvenile salmonid production and microhabitat selection in small southeast Alaska streams. Ph.D. Dissertation, Montana State University, Bozeman, Montana, USA.

the adjacent structure. Often, it appeared that females attempted to dig underneath WD, which influenced redd depth also. Sedell and Swanson (1984) have suggested that such debris may create secondary currents that sweep fine sediment away from spawning beds and this may be a factor in redd site selection. In concurrence with Sedell and Swanson (1984), the increased association of redds with WD during increased periods of rain may be an attempt by the spawning female chinook to evade the increased sediment loads during these periods. However, increased WD from wind damage during storms may simply increase the chance for association. Further studies of specific WD effects on redds, such as intergravel flows, dissolved oxygen, and reduction of aggression among spawning adults are needed.

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FIRST OBSERVATIONS ON SPAWNING BEHAVIOR IN THE GIANT SEA BASS

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The giant sea bass, *Stereolepis gigas*, is a slow growing, heavy-bodied piscivore, most recently classified in the Polyprionid family (Shane et al. 1997). It ranges from Humboldt Bay to the tip of Baja California and extends into the Gulf of California (Miller and Lea 1972). Specimens have been reliably aged at up to 75 years and may reach 90–100 years (Fitch[1] 1969). The largest specimen on record was a 256 kg individual caught off Anacapa Island, California in 1968. Spawning in the giant sea bass occurs primarily from July to September (Love 1991) and data on age at first maturity suggests that both sexes mature at 22–27 kg and 11–13 years of age (Fitch[1] 1969).

Most of the current biolgoical data on the giant sea bass have been collected in conjunction with other studies and little information exists on its habits and behavior. Fish behavior in general is difficult to observe and such brief episodes as courtship and spawning may best be described by observing captive individuals. Ephemeral color changes associated with courtship and spawning have been frequently described in large tropical and sub-tropical fishes (Gilmore and Jones 1992). However, spawning behavior and color changes in the giant sea bass have not been previously recorded. The objectives of this note are to: 1) describe spawning behavior during an actual spawning event, and 2) describe in detail color variations between male and female giant sea bass during pre-spawning activities.

Observations were made on captive individuals at 2 locations: Hubbs-Sea World Research Institute Marine Fish Hatchery (Hubbs) in Carlsbad, California and Long Beach Aquarium of the Pacific (LBAP) in Long Beach, California. A total of 3 separate spawning events was recorded between May 1998 and June 1999. Observations at the Hubbs facility were made visually and with a Sony Hi 8 (Sony, Inc.[2], Sony Corporation of America, San Diego, USA) video camera. The 2 giant sea bass observed were originally collected by hook and line off Oceanside, California on 15 January 1999. They were transported to Hubbs and held in a quarantine tank for 10 weeks. On 31 March 1999, the giant sea bass were transported to a large fiberglass viewing tank. Just before transport gamete tissue was removed from each fish using a catheter and analyzed under a stereomicroscope to determine sex. The larger individual was female and weighed approximately 50 kg at the time of transfer. The smaller fish was male and weighed approximately 31 kg. The circular viewing tank measured 3 m high by 5 m in

[1] Fitch, J.E. 1969. Offshore fishes of California. Fourth revision. California Department of Fish and Game, Sacramento, California, USA.

[2] Mention of trade names does not imply endorsement by the California Department of Fish and Game.

diameter and held approximately 34,200 liters of sea water on a flow-through system. Located at the front of the tank were 2 large, 5-mm thick acrylic viewing windows 1 m x 1 m, positioned one above the other. All observations were made through these viewing windows. Two large flourescent lights were set on timers and placed at the top of the tank to simulate daylight. This tank had no sea water temperature control.

Observations at LBAP were also made visually and with a Sony[2] Hi 8 video camera. The female giant sea bass was donated to LBAP by the Stephen Birch Aquarium, San Diego, California in January 1998 and had been in captivity there since 1992. Sex determination was made by the catheter method before transport to LBAP. When transferred, the female giant sea bass was estimated to weigh 55–60 kg. The male was donated to the aquarium on 7 January 1998 by Hubbs and just before transfer to LBAP it weighed 32 kg. Sex determination of the male was done at Hubbs. The giant sea bass pair were held in the 9 m high, 645,000-liter kelp forest observation tank near the entrance of the aquarium. Observations were made through the 8.2 m high by12.2 m wide observation window at the front of the tank. Computer controlled temperature and light regimes were maintained to simulate conditions in the wild. Each spawning pair displayed sufficient sexual size differences to distinguish the sexes during these observations.

Three spawning episodes were observed, 1 at Hubbs and 2 at LBAP. The Hubbs spawn occurred on 28 May 1999 between 1500 and 1600 hours. The tank temperature at the time of the spawn was 18.5°C and the light regime was set for 10 hours light and 14 hours darkness. No viable eggs were recovered from this spawn.

The first LBAP spawn occurred on 28 May 1998 at approximately 1630 hours. The tank temperature was 18.5°C and the light regime was 12.5 hours light and 11.5 hours darkness. No viable eggs were collected from this spawn. The second LBAP spawn occurred on 23 June 1999 at approximately 1830 hours and was videotaped by aquarium personnel. The tank temperature was 18.5°C and the light regime simulated summer conditions:14 hours light and 10 hours darkness. A total of 200 ml of fertilized eggs was collected from this spawn. Attempts to culture the eggs at Hubbs failed; none survived past the 3rd day of development. All individuals involved in the spawning events displayed similar, if not identical, color dimorphism between the sexes.

During the non-spawning season, mature giant sea bass coloration is typically gray to dark brown dorsally, fading to a light copper-brown ventrally (Fig. 1a). Dark spots above and on the lateral line are also prevalent on midsized individuals (45–115 kg). Large whitish patches are also clearly visible on the ventral surface of the caudal peduncle, directly anterior to the anal fin, and directly posterior to the pectoral fins. Larger individuals (135–230 kg) are entirely dark brown to copper with a gray to white underside. Individuals may also display a dark saddle marking located just posterior to the head and above the opercle. All specimens observed during this study retained the coloration of Fig.1a during non-spawning activity and had no apparent sexual color dimorphism.

During pre-spawning episodes, male and female giant sea bass underwent extreme sexual color dimorphism (Fig. 1b). Males appeared lighter, with spots on the body of the fish becoming very prominent. All fins, including spinus portions, were light and

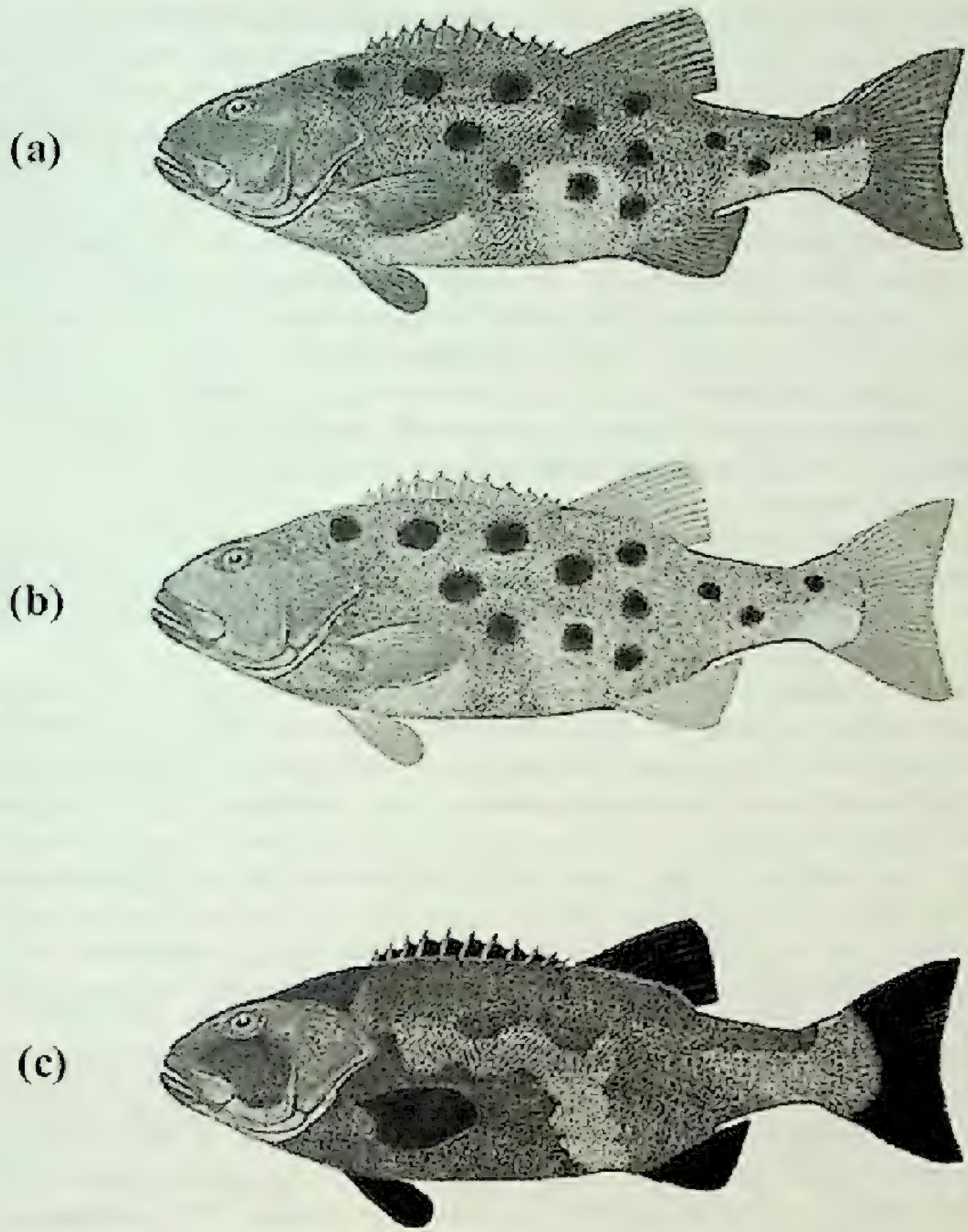

Figure 1. Three different color patterns of the giant sea bass, *Stereolepis gigas*: (a) mature male and female non-spawning coloration, (b) mature male coloration during pre-spawning and spawning episodes, (c) mature female coloration during pre-spawning and spawning episodes. Original illustrations by Howard Hammann (Eschmeyer and Herald 1983). Original plate color is brown. Tone and shading modifications were made by Tim E. Hovey.

streaked with white; the anal fin was almost completely white. The ventral or abdominal patch, between the pectoral and anal fin and extending to the lateral line, was gray-white. The caudal peduncle was noticeably lighter than the rest of the body, with the ventral surface displaying a distinct white patch. The entire head appeared

gray-white, gradually fading into a light bronze near the top (Fig. 1b). This color variation was retained by males participating in spawning behavior throughout pre-spawn observations.

Females became dark brown during spawning episodes, totally obscuring the characteristic spots (Fig. 1c). All fins became dark brown to black, with no white streaks visible. The ventral or abdominal patch was completely dark except directly in front of the anal fin where a whitish patch extended from the ventral surface to the lateral line area. The caudal peduncle displayed a dark brown dorsal surface, which faded to a whitish ventral surface. The head of the female showed 2 distinct markings not seen in the male: a dark brown patch extending from the eye to the pre-opercle and forward to the maxilla and a dark saddle mark at the top of the head and extending anteriorly beyond the eye and posteriorly to under the dorsal fin. This color variation was retained by the females participating in the spawning behavior throughout pre-spawn observations.

Pre-spawning behavior began with the male actively pursuing the female. Females often displayed bite marks or scrapes at or near the anal fin, presumably caused by aggressive males during courtship. Very little territorial or aggressive behavior was observed outside of the spawning season.

The male actively pursued the female and was never far from her once the pre-spawning behavior was initiated. The female frequently slowed to allow the male to approach and then abruptly swam a short distance away. This process was repeated continuously until the actual spawn occurred. During the pursuit, the male was usually positioned below and behind the female and would always attempt to nudge the abdominal area of the female when allowed to approach. This behavior lasted anywhere from several hours to several days before the actual spawn occurred. Courting pairs often approached and circled each other, laterally displaying as they slowly circled. The female usually broke the circle and swam off, followed closely by the male.

The female initiated the actual spawning sequence by swimming in a wide circular pattern 8–10 m in diameter at the bottom of the tank. With the male positioned on the inside of the female, the circling pair spiraled to the surface. At the surface, the circular pattern tightened to about 2–3 m in diameter. The female then oriented into a head down position with her caudal fin at or near the surface. The male remained positioned on the inside of the circle and began to nudge the female's abdomen near the anal fin. As the pair continued to circle, the swimming speed became more rapid and both fish beat the surface with their caudal fins as they swam. The pair began to tilt slightly along the dorsal-ventral axis as the speed of the circling increased. At the completion of 1 full rotation at the surface the female began to release eggs, followed closely by the male's release of sperm. During this release, the swimming became very rapid and both male and female displayed exaggerated caudal movements that agitated the surface vigorously. Four complete rotations by the pair, lasting approximately 15 seconds total, completed the spawn. The pair then separated and went to opposite areas of the tank. Non-spawning color patterns usually returned in less than an hour after pair separation.

Variability in color phases in the giant sea bass in association with intraspecific behavioral activities suggests that these behaviors have a communicative function. Drastic coloration changes exhibited by the female during the pre-spawn period appear to initiate a behavioral response in the male, most noticeably an increase in male aggression. During the pre-spawn period, each male giant sea bass chased the female as well as other species in the tank that came close to the female during courtship. This aggression towards other species was not observed during the non-spawning season. However, it is unclear whether the aggressive behavior seen by the male during courtship can be attributed to territorial defense or captivity.

While courtship behavior in giant sea bass has not been previously reported, they are known to gather in large numbers from various distances during the spawning season (Leet et al.[3] 1992). These gatherings are known as transient spawning aggregations and only occur during a very specific portion of 1 or 2 months of the year (Domeier and Colin 1997). Other species that gather in seasonal breeding aggregations have been shown to pair off and conduct the spawning event away from the group (Gilmore and Jones 1992) or actively defend breeding territories (Sadovy et al. 1994) as described here in some of the pre-spawning observations.

All 3 spawning episodes occurred at approximately the same time of day (1500–1830 hours) and with identical tank water temperature (18.5°C). All light regimes were set for 10 to14 hours of light. The temperature and photoperiod data gathered during this study agree with spawning conditions of giant sea bass in the wild (Love 1991). Thus the simulated wild conditions provided in the tanks should support similar behavioral patterns. However, it would be good to observe spawning in the wild to confirm the observations made here in captivity.

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A SELF-CONTAINED MOBILE SURGICAL TABLE FOR FISH

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During fish culture or while holding specimens for aquarium display, examinations or minor operations frequently need to be done on large individuals. For small fish such procedures can be relatively easy; however, when procedures are lengthy or individual specimens are large, injury or death is possible. The main problem during a procedure is maintaining an adequate flow of water over the gills to sustain the fish. Additionally, procedures must frequently be conducted in places with minimal laboratory equipment and when moving the specimen to better facilities is not possible. The mobile surgical table described here is a relatively inexpensive and easily constructed platform for conducting procedures on large fish in areas without extensive laboratory equipment.

The mobile surgical table was designed to: 1) be easily transported, compact, and self contained; 2) provide a stable working platform for many kinds of procedures; 3) be capable of re-circulating water; and 4) be easily cleaned and stored. The surgical table was designed and constructed at Hubbs-Sea World Research Institute, Marine Fish Hatchery, and used there for procedures on brood fish. The basic design consists of a working platform, 4 vinyl-treated canvas velcro straps, 2 plastic restraining rails, a wheeled polyurethane cart, two 45-liter water reservoirs, a small re-circulation pump, a PVC valve system, and a work light (Fig. 1, Table 1).

The working platform is constructed from 2 pieces (40 x 120 x 19 cm) of plywood connected at an angle to form a beveled center for adequate water drainage. This unit is then coated with fiberglass, painted with a non-skid marine paint to minimize abrasion to the fish, and secured to a single piece of plywood of the same overall dimensions for stability. Four vinyl-treated canvas restraining straps, 1.22 m long and 7.6 cm wide, are attached with velcro straps to 109-cm long plastic rails (standard boat railings) at the top and bottom of the platform. The rails are used as securing supports for the restraining straps. A 5-cm diameter drain hole is drilled through the center of the platform at one end, and a PVC 2:1 reducer epoxied into the hole.

The working platform is attached to a wheeled polyurethane Rubbermaid utility cart (Rubbermaid, Inc.[1], Baltimore, Maryland, Model 62122) (Fig. 2) so that the drain hole overlaps the top of the utility cart. A 10 cm x 10 cm x 0.5-m wooden spacer is attached beneath the platform, at the end opposite the drain and on top of the cart to create an adequate drain angle. Mounting screws secure the working platform to the utility cart. Several drain holes are drilled into the floor of the polyurethane utility cart to remove residual water. A ground fault interrupter power strip is attached beneath

[1] Use of product names does not imply endorsement by the California Department of Fish and Game

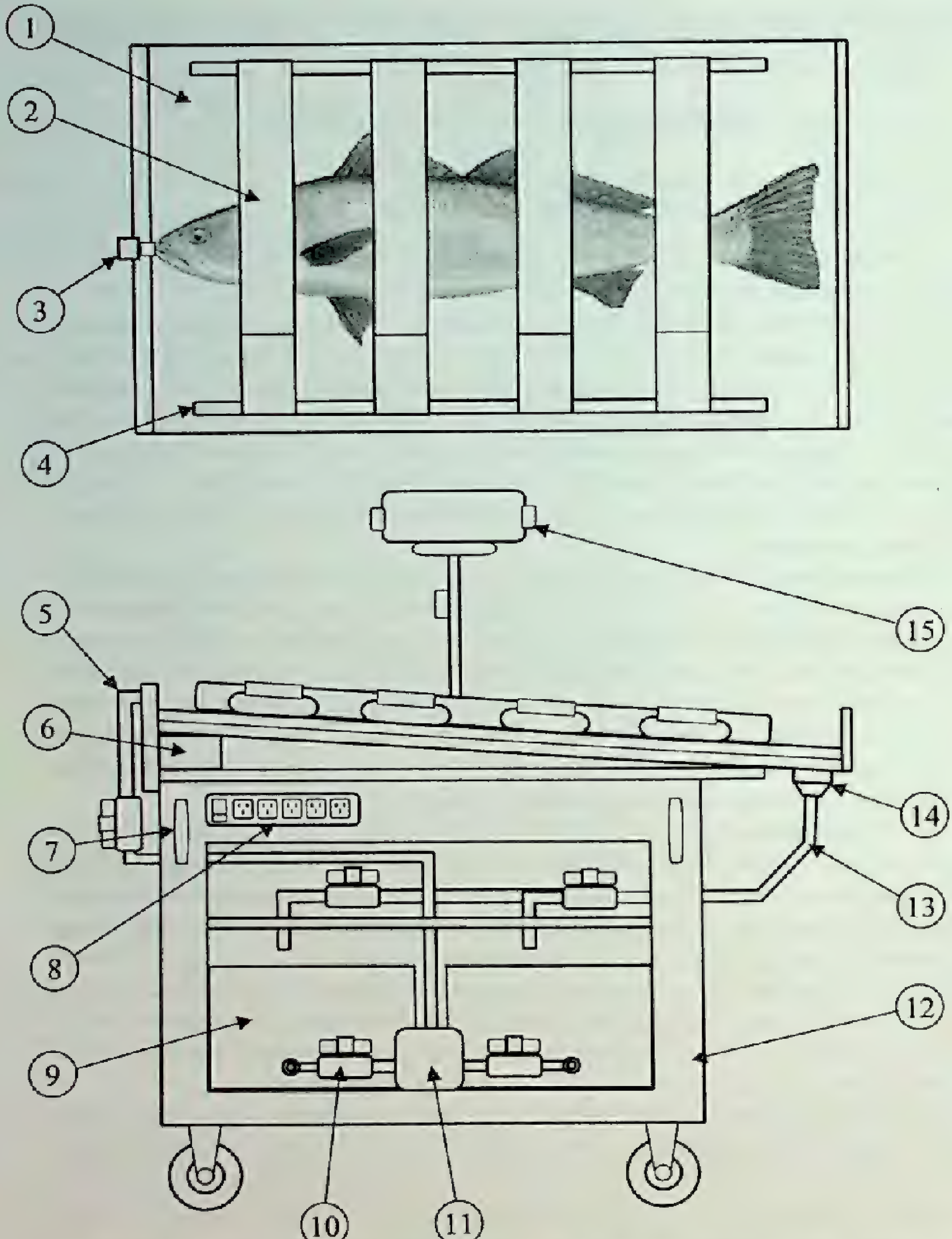

Figure 1. Top and side view of the mobile surgical table. Items are: 1) working platform, 2) vinyl-treated canvas velcro straps, 3) mouthpiece, 4) plastic rails, 5) flexible tubing, 6) wooden spacer, 7) power cord storage cleat, 8) power strip, 9) Rubbermaid[1] 45-liter reservoir, 10) valve, 11) Rio[1] 180 re-circulation pump, 12) Rubbermaid[1] polyurethane utility cart, 13) PVC pipe, 14) reducer drain, 15) work light. Illustration by T.E. Hovey.

Table 1. Parts list for the mobile surgical table.

Quantity	Item
2	40 x 120 cm pieces of 19-mm thick plywood
4	vinyl-treated velcro restraining straps, 1.22 m x 7.6 cm
1	polyurethane utility cart (Rubbermaid[1] Model 62122)
2	plastic 45-liter reservoir containers (Rubbermaid[1] Model RHP 2223 HGR)
1	re-circulation pump (Rio[1] 180, Model E160713)
1	60 watt halogen work light
5	2.5-cm PVC valves
1	2.4-m section of 2.5-cm PVC pipe
1	2:1 PVC reducer
1	meter of flexible tubing, 1.28 cm diameter
2	plastic restraining rails, 109 cm long (standard boat rails)
2	power cord storage cleats
1	ground fault interrupter power strip
1	extension cord, 15 m long
1	10 cm x 10 cm x 0.5-m wood spacer
1	0.64-cm PVC reducer fitting (small mouthpiece)
1	1.27-cm PVC reducer fitting (large mouthpiece)

the platform to power the utility light and the re-circulation pump. Two plastic cleats are attached to the front of the utility cart to store the extension cord.

Two 45-liter plastic containers (Rubbermaid[1] Model RHP 2223 HGR) are used as re-circulation reservoirs for medicated and non-medicated sea water. To maximize the amount of available water that can be pumped from the reservoirs, each is fitted with a 2.5-cm PVC valve near the bottom. Both containers are placed on the cart floor but are not attached to it. A small re-circulation pump (Rio 180, Rio Inc.[1], Minneapolis, Minnesota , Model E160713) capable of 454 liters/hour is attached to the cart floor, between the re-circulation reservoirs. The platform drain, re-circulation pump, and re-circulation reservoirs are plumbed together using 2.5-cm PVC pipe (Fig. 1) with valves placed in the circuit so that either or both reservoirs can be drawn upon during procedures. A length of flexible tubing (1.27 cm diameter) with an in-line flow adjustment valve is fed from the outgoing re-circulation pump nozzle and attached to the upstream end of the working platform. At the end of the flexible tubing, 0.64- and 1.27-cm PVC reducer fittings are placed and are used as mouthpieces to accommodate fish of different sizes. Finally, a halogen working light is attached to the side of the utility cart. Power cords for the power strip, working light, and re-circulation pump are secured together and attached to the utility cart beneath the working platform to reduce the possibility of water damage. A 15-m extension cord is used to bring power to the table.

When the mobile surgical table is in operation, the re-circulation pump draws water from the reservoirs through the flexible tubing. The water exits the mouthpiece, into the mouth and over the gills of the fish. Flows can be adjusted using the in-line valve from 1.9 to 9.5 liters/minute, depending on the size of the specimen. Special mouthpiece adapters can be fitted to the flexible tubing to accommodate varying sized individuals. The water then flows down the work table to the drain and back to the

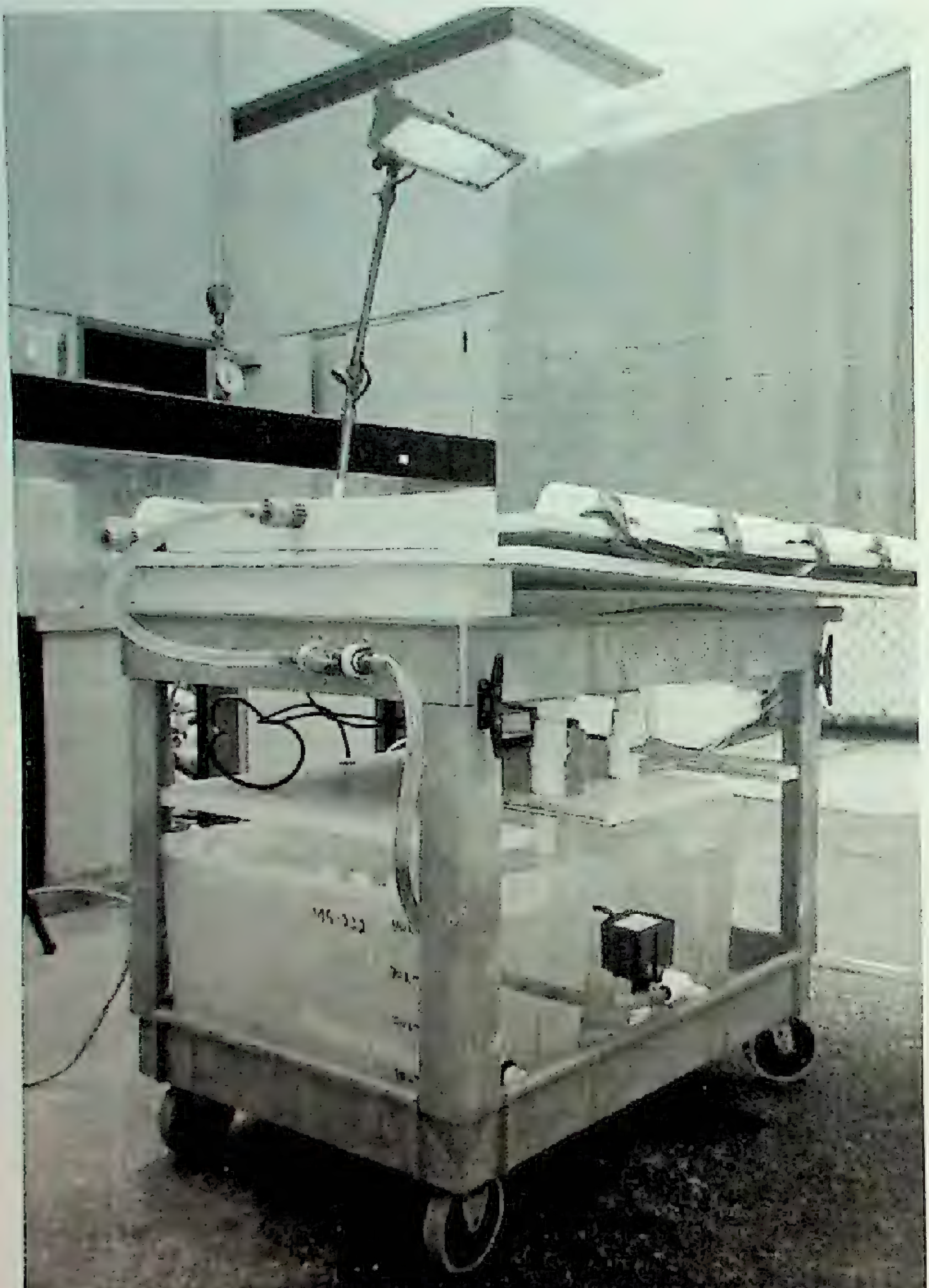

Figure 2. Mobile surgical table, prepped and ready for a procedure. Photograph by E. Johnson of the Steven Birch Aquarium.

initial reservoir. The drain system easily accommodates the volume of water pushed by the re-circulation pump so the system does not overflow.

Before a procedure, the mobile surgical table is powered up, allowed to run, and monitored to assure that everything is in working order. The fish is then anesthetized using MS222 (tricaine methanesulfonate) in its home tank. Once the fish is adequately sedated, it is gently placed on the table and the flexible tube and mouthpiece put in place. Little or no struggling takes place on the table. A wet cloth is placed over the eyes to reduce stress and the fish is strapped down using the restraining straps. The table is set up with 1 re-circulation reservoir containing the same concentration of MS222 as the home tank and the other reservoir containing fresh sea water. The medicated reservoir is the primary source of water during normal procedures, while the fresh sea-water reservoir is used for lengthy procedures or when the fish is weakening. During a procedure, the heart beat of the specimen is monitored by observing the beat at the gill arches. If the beat becomes shallow, the fish is switched from medicated water to non-medicated water by simply turning 2 valves. When the procedure is complete, the fish is removed from the surgical table and placed into a non-medicated tank to recover. Due to the degradation properties of MS222 and the build-up of mucus and scales, the primary source water reservoir should be changed frequently, especially if procedures are lengthy or if multiple (>10) specimens are being processed.

The table is easily cleaned by rinsing the working platform with fresh water and draining the reservoirs. The re-circulation reservoirs are then re-filled, the pump turned on, valves opened, and the unit allowed to run dry through a flexible tubing attached to the drain. This allows the drain water to be discarded instead of returning to the reservoir, thus rinsing the lines of sea water.

Over 200 fish of several species weighing 2–20 kg have undergone procedures without mortality using this surgical table. While a typical procedure lasts <5 minutes, a juvenile giant sea bass, *Stereolepis gigas*, was kept on the table for 55 minutes while a delicate eye operation was successfully performed.

ACKNOWLEDGMENTS

I thank the personnel of the Hubbs-Sea World Research Institute for the opportunity to design and build the surgical table and E. Johnson, Steven Birch Aquarium, for providing the photographs of the table in action.

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AN ECONOMICAL SAFE-HOUSE FOR SMALL MAMMALS IN PITFALL TRAPS

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Live capture via pitfall traps is a technique commonly used to census ground-dwelling invertebrates, amphibians, reptiles, and small mammals (Corn 1994, Murkin et al. 1994, Jones et al. 1996). When properly conducted, this technique can provide valuable information on local faunas without significant harm to resident amphibian and reptile populations (Bury and Raphael 1983); however, small mammals caught in such traps frequently die of exposure (Bury and Corn 1987, Jones et al. 1996). During winter 1999–2000, we used pitfall traps to salvage adult and juvenile California tiger salamanders, *Ambystoma californiense*, from a breeding pond site in the vicinity of south San Jose, Santa Clara County, California. In the course of our work, we encountered a substantial number of small mammals in our pitfall traps that were at risk of exposure to the elements. We designed a "safe-house" to protect these animals that would not interfere with salamander captures.

The small mammal safe-house is constructed with 5-cm diameter polyvinyl chloride (PVC) Schedule 40 pipe and pipe cement. The pipe is first cut into 12.5-cm and 12.0-cm lengths (i.e., a standard 3.05-m length of pipe can be cut into 48 lengths of 12.5 cm and 24 lengths of 12.0 cm in order to make 48 safe houses). Next, a 5-cm diameter PVC cap is glued on one end of each of the 12.5-cm lengths of pipe. Finally, the 12.0-cm lengths of pipe are cut in half lengthwise and each half is glued horizontally to each of the 12.5-cm lengths of pipe in order to provide a stable base. The resulting safe-house (Fig. 1) is ready to use once the glue has dried for 12 hours.

Safe-houses are placed base down in the bottom of pitfall traps and the center of each is 1/3 filled with 100% cotton batting (available from any fabric store). Only 100% cotton batting should be used, because man-made fabrics are insufficient to keep small mammals warm during damp situations. We have found the addition of food for small mammals (such as bird seed) to be unnecessary, as pitfall traps are checked at least daily (and even more frequently if shrews are present). During each check of pitfall traps, safe-houses are manually removed from each trap and examined for occupancy. This procedure also allows observation of target amphibians and reptiles in the trap when the safe- house has been occupied. Cotton batting is replaced as needed (i.e., when dampened with moisture or pulled out of the safe-house). We have also found that placing a damp sponge under the base of the safe-house provides a suitable, burrow-like hiding place for salamanders and some invertebrates.

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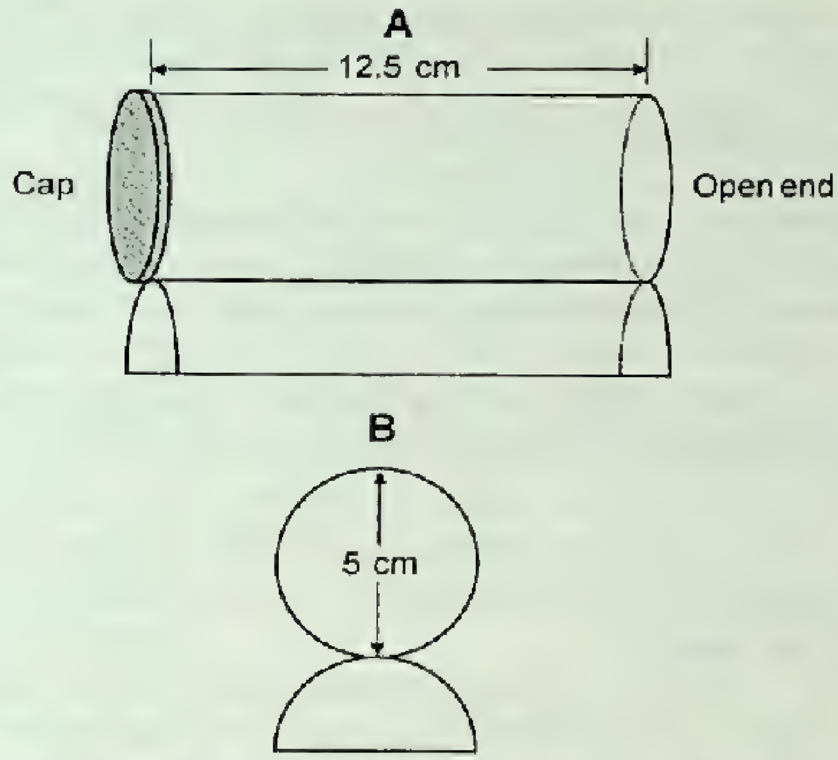

Figure 1. Side view (A) and front view (B) of the assembled rodent safe-house constructed with 5-cm diameter PVC pipe.

In the course of our salamander trapping operations, we recovered a total of 5 dead small rodents over 5 days when pitfall traps included wet sponges, but lacked safe-houses. With safe-houses placed on top of wet sponges, we found only 1 ornate shrew, *Sorex ornatus*, dead out of 33 small mammals trapped over a 70-day period.

Some researchers using pitfall traps to capture amphibians have used long sticks or wires to allow escape of non-target rodents and invertebrates (N.J. Scott Jr., U.S. Geological Survey, personal communication). We believe our small mammal safe-house to be more suitable for a wide variety of situations, especially when one wants to obtain data on small mammals that have been captured. Placement of the entire safe-house in the pitfall trap ensures that no target amphibians and reptiles will escape. Because of the minimal cost (currently US$1.00 per safe house), ease of construction, and short processing time for checking each safe-house, use of these devices should be considered for any pitfall trapping study.

ACKNOWLEDGMENTS

We thank the California Department of Fish and Game for issuing permits that allowed us to conduct this work and N.J. Scott Jr. for information regarding pitfall trap methodology. D.S. Johnston assisted with checking pitfall traps.

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California Fish and Game 87(2):74-75 2001

IN MEMORIAM

WILLIAM A. DILL (1910–2000)

William A. "Bill" Dill, born 19 August 1910, died on 5 December 2000 in Lewisburg, West Virginia at the age of 90. He was one of the last survivors of the class of certified fisheries scientists trained in the shadow of David Starr Jordan at Stanford University.

Bill was an active fisheries scientist for the California Department of Fish and Game (CDFG) for 17 years. He conducted hundreds of surveys on lakes and streams in the state, producing many scientific papers and developing state policy on California's inland fisheries. Mr. Dill became the CDFG's Supervising Fishery Biologist and administered research and management activities for the last several years he spent in state service.

Among the skills he honed while conducting his field surveys was that of a talented dry fly angler who could cast a fly so realistically that it is said that swarms of ardent males would follow his back casts along the streams and rivers where he fished. One catch that was not reported occurred when he snagged his daughter's arm on a back cast that rolled several feet farther than expected.

In 1955 Bill joined the Fisheries Division of the Food and Agriculture Organization (FAO) of the United Nations and soon became the Chief of the Inland Fisheries Resources Branch in Rome. During his 17 years with FAO, Bill established world-wide programs for inland fisheries research and management. He authored over 150 scientific papers; established the European Inland Fisheries Advisory Commission, of which he was secretary for 6 years; and organized the world's 1st international fisheries meeting in Helsinki in 1956. His international work took him to 67 countries and he coordinated FAO's activities with over 12 international agencies.

Among his many noteworthy publications were the massive volumes on the fresh water fisheries of Europe and "History and status of introduced fishes in California, 1871–1996," which he co-authored with Almo Cordone as California Fish and Game Fish Bulletin 178. Bill subsidized the publishing costs of this Fish Bulletin from his own funds.

Among 8 professional societies to which he belonged, he was an active member of the American Fisheries Society and American Institute of Fisheries Research Biologists. He was president of 2 angling clubs in California and a collector of wine labels from all over the world, which were all classified, mounted, and donated to the University of California, Davis.

After retirement he was a sought-after consultant for the United Nations Development Programme, United States Agency for International Development, numerous countries, and private and government organizations.

Finally, even though Bill was a natural humorist with a wit as dry as his artificial flies, his commentaries, both oral and written, engendered an appreciation that Bill's talents as a scientist and a friend were not to be taken lightly.

The numerous initiatives that Bill Dill carried out during his productive lifetime give him a world-wide place of honor in fisheries science and management. But even more than that, it was an unparalleled privilege to have known Bill as a treasured friend and international colleague for all of his professional life.

Bill was preceded in death by his beloved wife Gale on 31 July 1994. They are survived by 2 children, Nancy Kobel and William H. Tilson; Bill's brother, Franklin Dill; sister, Frances Chamberlain; 6 grandchildren; and 7 great-grandchildren.

– *Wm. Ellis Ripley*
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California Fish and Game 87(2):77-86 2001

CALIFORNIA FISH AND GAME EDITORIAL POLICY AND INSTRUCTIONS TO AUTHORS

California Fish and Game is a regional, scientific journal devoted primarily to the conservation and understanding of California's flora and fauna, but it also accepts papers from the west coast of North America and the northeast Pacific Ocean. Original manuscripts providing information of direct interest and benefit to California researchers and managers are welcome. The journal accepts the following types of contributions: 1) *Articles* include reports of studies of broad scope, critical reviews, and in-depth essays (perspective articles) on subjects of concern to the professional and layperson. 2) *Notes* are short papers of limited scope that present new knowledge worthy of publication. 3) *Comments* are opinions on topics already published in the journal; responses from the original authors will be invited.

If the journal's contents are reproduced elsewhere, the authors and *California Fish and Game* should be acknowledged.

THE MANUSCRIPT

Submit 4 copies (retain the original) of manuscripts directly to the Editors-in-Chief at the address on the inside, front cover of the journal, accompanied by a cover letter that 1) states the category (article, note, or comment) intended for the paper; 2) describes other manuscripts or published material that contain the same or similar information; 3) lists colleagues who have seen the draft manuscript; 4) lists potential referees; 5) specifically accepts page charges (US$40.00 per page); and 6) contains the phone and FAX numbers, and e-mail addresses of the corresponding author.

Manuscripts should be printed letter-quality on standard white bond paper. Draft figures and illustrations are acceptable for the initial review process. Double-space all material, including the abstract, text, figure captions, tables, and literature cited. Provide ample margins, at least 2.5 cm on all sides. Do not hypenate at the right margin or right-justify text.

Number pages, including tables and literature cited. Type each table on a separate sheet. Each section must immediately follow the previous section; do not start on a new page. Include an initial statement in the introduction explaining the purpose or objective(s) of the work. Be as specific as possible when describing the purpose or objectives of the work.

Articles must be introduced by a concise, single-paragraph abstract. Notes do not include an abstract.

Very long articles should also have a concise summary, understandable without reference to the text.

Avoid the passive voice, lengthy tables or appendices, repetition, and long lists of little interest except to the author. Personal pronouns may be used when they do not create strained phrasing.

Punctuate and proofread carefully. Check all equations for accuracy. Assure consistency between "Literature Cited" and citations in the text. Inattention to detail aggravates editors and affects referees' opinions of the manuscript.

The journal follows the CBE Style Manual (Sixth Edition) in most matters, but use these instructions and a recent issue of *California Fish and Game* as definitive guides in the correct preparation of manuscripts.

UNITS OF MEASUREMENT

The metric system is used exclusively in *California Fish and Game* because of its worldwide acceptance. The modernized metric system, "Systeme International d'Unites" (SI), is the preferred system. This system provides unambiguous symbols, standard in all languages, for units of measurement. The CBE Style Manual contains a discussion of the SI, as well as conversion factors from common English measurements to metric.

TABLES AND FIGURES

Tables and figures are numbered consecutively beginning with "1". Refer to tables and figures by number in the manuscript. Do not say "as shown in the following table," because the table in question may not immediately follow that statement in final placement.

Make complete statements of fact in the text. Use figures and tables only as supporting references. For instance, avoid statements like "Table 1 shows the estimated rate of exploitation and expectation of deaths from natural causes." Rather, state: "Estimated exploitation rate and expectation of death from natural causes were 50% higher in 1962 than in any of the next 6 years (Table 1)." In this way the reader is never forced to search out Table 1 to understand the text.

In the text, abbreviate Figure as "Fig." Use initial capitals for "Fig." and "Table."

Tables

Think carefully about table layout; most tables can be formatted to fit the standard page width of the journal (119 mm). Deviate from this (portrait) format to landscape format only as a last resort.

Table headings should contain sufficient information for tables to stand alone without reference to the text. Capitalization in table headings should follow the same format as other text, as illustrated in example Table 1.

Table 1. Age at which the first spawning check was observed in scales from Sacramento suckers from Thomes Creek, California, 1981.

	Age (percent composition)			
Sex	4	5	6	7
Female	7.7	49.2	37.2	5.9
Male	8.3	58.3	31.1	2.2

In column headings and row labels, capitalize first letter of initial word only, as in "Age at maturity." Underline column headings, but do not include any other horizontal or vertical rules in tables. Horizontal rules, as shown in example Table 1, will be inserted by the editors.

Use tabs (1 tab between column headings and column entries), not the space bar, to space between columns. No other spacing should be included between columns.

Figures

Figure captions should contain sufficient information for figures to stand alone without reference to the text. Type all figure captions consecutively, double-spaced, on a separate page following the Literature Cited section at the end of the manuscript. Do not attach captions to figures.

Identify figures on the back with last name of author(s) in the upper left-hand corner and the figure number in the upper right-hand corner.

Submit figures that can be satisfactorily reduced to the format of the journal. Reductions should not exceed 50%. Take care that lines and lettering are large enough to be legible when reduced to the size of the journal page. Lettering style should be the same throughout.

Consider proportions of figures in relation to the page size of *California Fish and Game.* The usable printed page size is 119 by 187 mm. This must be considered in planning a figure, since the figure with its caption cannot exceed these limits. To the extent possible, figures should be sized and oriented so that they occupy only part of a page of the journal.

Maps are only necessary when they show detail, such as sampling sites, not available in a standard atlas. Maps should show the scale in kilometers and compass direction. Latitude and longitude on the appropriate borders are often desirable. An inset location map is generally useful.

Illustrations drawn to scale should be so indicated in the figure caption.

Photographs

Submit prints (black and white only) on glossy paper. Remember that the printed halftone will not be as clear as the photograph. A fuzzy photo cannot yield anything but a muddy printed product.

As for figures, consider the shape of the print. Crop items that distract from the central object such as out-of-focus foreground and overbalancing areas of sky.

Pack photographs carefully before mailing and provide backing. Cracks on prints will show in the halftone. Do not put paper clips on photographs. Never write on the back of photographs or figures with any object harder than a soft tip pen or china marking pencil.

Captions for photographs should include the name of the photographer and, if appropriate, the month and year in which the photo was taken. Use "Photograph by author" if that is the case.

TITLES AND SUBTITLES

Follow this pattern in setting up titles and subtitles:

TITLE IN CAPS

AUTHOR IN CAPS
Organization in Initial Caps
Complete Mailing Address in Initial Caps

MAJOR SUBHEAD - CENTER CAPS

Next Subhead - Center, Initial Caps Only

Third Subhead - Left Margin, Italicized, Initial Caps Only

Fourth subhead italicized - Indented as a paragraph with the text following like this sentence.

FOOTNOTES

A footnote with the author's name is used to reflect the present address of the author if different from the address while doing the work (e.g., [1] Current address:).

Use of footnotes should be minimized. Their most common use is for citation of nonprimary (gray) literature not appropriate for inclusion in "Literature Cited." If used, they should be denoted by superscript numbers, numbered consecutively (1, 2, ...) throughout the manuscript, and placed on a separate page after "Literature Cited" and before any figure captions.

Footnotes in tables should be consecutive lowercase letters (a, b, ...) and the sequence begins again in each table. Table footnotes should be placed below the body of the table.

MEASUREMENTS

Use Arabic numerals in preference to words when numbers are counts or measurements, as "7 quail" or "3 mm." Treat ordinal numbers in the same manner (3rd, 33rd). Never begin a sentence with an Arabic numeral (spell out the number) or use numerals for 2 consecutive numbers (e.g., "two 3-liter flasks," not "2 3-liter flasks").

Show temperatures in degrees Celsius with the abbreviation °C.

Give latitude and longitude in the form: 33°41'30"N, 118°09'05"W.

Dates are expressed as: 23 January 1998.

Use the 24-hour system for time of day: 1100 hours.

ABBREVIATIONS

Abbreviations should be used sparingly. The following abbreviations are used in *California Fish and Game* without definition:

alternating current	AC
centimeter(s)	cm
confidence interval	CI
degree (angular measure or degree Celsius)	°
degree Celsius	°C
degrees of freedom	df
direct current	DC
east	E
gram(s)	g
hectare	ha
kilogram(s)	kg
kilometer(s)	km
lethal concentration, 50%	LC50
lethal dose, median	LD50
logarithm (base 10)	log, $\log_{10}$
logarithm (base e)	ln, $\log_e$
meter(s)	m
microgram	µg
micron(s) (10^{-3} mm)	µm
milligram(s)	mg
milliliter(s)	ml
millimeter(s)	mm
minute(s) (angular measure)	′
north	N
parts per billion	ppb
parts per million	ppm
parts per thousand	‰
percent	%
probability	*P*
second(s) (angular measure)	"
south	S
species (taxonomy only, singular)	sp.
species (plural)	spp.
standard deviation	SD
standard error	SE
volt	V
west	W

Express measurements of area and volume with exponents, not with letter abbreviations (e.g., "m^2," not "sqm" and cm^3," not "cc").

Express ratios and densities with a slash (/) (e.g., number/m^2) if there is only 1 unit in the denominator. Multiple slashes in an expression are ambiguous, so write a

unit such as "catch per angler per day" as "catch/(angler·day)," not "catch/angler/day."

CAPITALIZATION

Do not capitalize common names of organisms.

Capitalize bay, city, county, river, street, and similar words only when they form part of a name: Humboldt Bay, Shasta County, City of Stockton; but Humboldt and Shasta counties or American and Sacramento rivers.

Do not capitalize northern and southern in the expressions northern California and southern California. Capitalize the word State when it stands alone and refers to California. Capitalize Department in referring to the Department of Fish and Game.

STATISTICAL RESULTS

Results of statistical tests should be presented in full in the text. This includes the value of the test statistic (e.g., F =, t =, χ^2 =), degrees of freedom (df =), and probability of wrongly rejecting the null hypothesis (P =). Place the test results in parentheses following the statement of the statistical conclusion, using correct internal punctuation (e.g., F = 5.61; df = 1, 9; $P = 0.02$). Probability can be expressed as an exact value or as greater than (>) or less than (<) a critical value, but the same convention should be used throughout the manuscript. If multiple statistical tests were conducted and all yielded the same (significant or nonsignificant) results, each test statistic need not be presented. Instead, provide the name of the test and the relation of the resultant probabilities to the critical value (e.g., ANOVA, all $P < 0.05$).

In tables, if probabilities are not presented in a separate column, indicate significance of tabular values with asterisks (*, **, ***) and define the values for these symbols in the figure caption (e.g., * $P < 0.05$, ** $P < 0.01$).

PREPARATION OF COPY

Wide availability of word processing software allows production of copy with boldface, italics, small caps, etc. Use typesetting conventions (e.g., 1 underline for italics) only if appropriate word processing software is not available.

Scientific names are always italicized. Italicize only the generic name when unknown or multiple species are denoted, as *Sebastes* sp. or *Sebastes* spp. Scientific names should be set off with commas, as "mosquito fish, *Gambusia affinis*, in Golden Pond."

Spell out fish length designations, followed by abbreviations in parentheses (FL, SL, or TL), the first time you use them. Thereafter, use abbreviations only. Better yet, describe the measurement technique in the Methods section and eliminate the subsequent need for length designations.

Capitalize and italicize names of vessels: *LONGFIN*, *DAVID STARR JORDAN*.

In the text, italicize names of books, journals, and similar literary works. Do not italicize citations in the Literature Cited section.

Be especially careful with hyphens. Most authors tend to hyphenate many words

which should be written unhyphenated. Note particularly that commonly used prefixes and suffixes (such as inter, like, mid, non, over, post, pre, semi, sub, under) usually are not hyphenated. Compound modifiers normally are hyphenated (e.g., 25-mm specimen, deep-water fishes), unless the first word of the compound modifier is an adverb.

Use parentheses and Arabic numerals to label enumerations included in a sentence or paragraph, as "The primary objectives of this study were to determine 1) food habits, 2) effects of hunting, and 3) extent of depredations on agricultural crops of wintering mallards."

COMMON AND SCIENTIFIC NAMES

The scientific name of a species should be introduced the first time the common name is used in the abstract and in the text. Thereafter, use the common name in text, tables, and figures unless no recognized common name exists. If a great many species are under consideration, it is permissible to use common names in the text and to list common and scientific names in an appendix or table. Do not include a scientific name in the title unless no common name exists or the manuscript deals primarily with systematics or a range extension of a species that is rare in California.

ACKNOWLEDGMENTS

Acknowledgments generally should be in the order of assistance rendered or alphabetized within an organization if more than 1 individual gave the same help. Grants-in-aid and other funding sources should be included in this section. Use only initials of given names, but spell out the entire names of organizations, unless an abbreviation has been defined earlier in the text.

LITERATURE CITED

List citations, double-spaced, in alphabetical order at the end of the manuscript. Your list must be headed "LITERATURE CITED." All entries must be cited in the text.

Avoid extensive references to nonprimary (gray) literature, such as unpublished agency reports, M.S. theses, Ph.D dissertations, and technical reports with limited distribution. Reports with limited or no peer review fall into the gray literature category. Gray literature cited in the text should not be included in "Literature Cited"; instead, it should appear on a separate page following "Literature Cited" and should follow the same format as primary literature citations (see "Footnote" section).

Check all citations carefully against the original publications, especially titles and dates. Refer to them in the text using the name-and-year system. Where there are 3 or more authors, use "et al." for the junior authors in the text, as "Turner et al. (1969)," but list all authors in "Literature Cited."

Multiple references cited in the text should be in chronological order, as "(Lea 1975, Herrgesell 1984, Hashagen 1985)." A gray literature citation should have the

superscript footnote number following the author's name, as "Zielinski[1] (1992)." Citations for direct quotations in the text should include the page number from which the quotation was drawn, as "(Moyle 1976:144)."

Write out the names of periodicals completely (e.g., Transactions of the American Fisheries Society, California Fish and Game, Wildlife Monographs). Include the periodical issue number only if page numbers are not consecutive from issue to issue. Omit the number of pages in books, bulletins, and symposia proceedings if the entire publication is cited. Spell out the names of cities and states (or other appropriate governmental or geographic unit) where publishers are headquartered and include the country (e.g., USA, Ireland).

Examples of the general style used in *California Fish and Game* are shown below.

Periodical or journal:

Duffy, J.M. and H.J. Bernard. 1985. Milkfish, *Chanos chanos* (Forsskol, 1775), taken in southern California adds new family (Chanidae) to the California marine fauna. California Fish and Game 71:122-125.

Article as part of a bulletin or book:

Quast, J.C. 1968. Fish fauna of the rocky inshore zone. Pages 35-55 *in*: W.J. North and C.L. Hubbs, editors. Utilization of kelp bed resources in southern California. California Department of Fish and Game, Fish Bulletin 139.

Book:

Watt, K.E.F. 1968. Ecology and resource management: A quantitative approach. McGraw-Hill Co., New York, New York, USA.

Two or more papers by same author in same year:

In text: (McCoid and Fritts 1980a, b).

In "Literature Cited":

McCoid, M.J. and T.H. Fritts. 1980a. Observations of feral populations of *Xenopus laevis* (Pipidae) in southern California. Bulletin of the Southern California Academy of Science 79:82-86.

McCoid, M.J. and T.H. Fritts. 1980b. Notes on the diet of a feral population of *Xenopus laevis* (Pipidae) in California. Southwestern Naturalist 25:272-275.

These general rules apply:

1) Only proper nouns are capitalized.

2) Initials are substituted for given names.

3) The words "volume" and "number", or their equivalents in foreign languages, are not used in citing periodicals.

4) Unpublished papers are not cited in "Literature Cited". If they must be used, they may be footnoted. Papers "in press" can be cited if they are being published in the peer-reviewed primary literature; if in the gray literature, they should be footnoted.

5) Personal communications are not cited in "Literature Cited"; they are cited in the text as "(A.J. Cordone, California Department of Fish and Game, personal communication)." Subsequent personal communications would be cited as "(A.J.

Cordone, personal communication)."

MANUSCRIPT PROCESSING

Upon receipt by the Editors-in-Chief, a manuscript will be acknowledged and forwarded to the appropriate associate editor, who will then have the manuscript reviewed by at least 2 referees. When reviews are complete, the associate editor will send the reviewed manuscript, with a recommendation for acceptance or rejection, back to the Editors-in-Chief. The Editors-in-Chief will forward referees' comments and an acceptance or rejection notice to the author with further instructions. Manuscripts are generally published in the order accepted by the Editors-in-Chief, within space limitations of the journal.

FINAL FORM OF MANUSCRIPT

An electronic copy of the final, accepted manuscript is required before publication. This diskette copy should be in PC (not MacIntosh) word-processor or text format. Tables, figure captions, and footnotes can be included in the same document as the text, or in separate documents. If they are included in the same document, tables should each be on a separate page; figure captions can all be included on 1 page, as can footnotes. As noted earlier, it is imperative that spaces between columns in tables be created with tabs, not the spacebar, with only 1 tab between columns. Do not include horizontal or vertical lines in tables; however, column headings should be underlined. Also, do not use the "table" function in your word processor; it will not translate into our desktop publishing software. If the diskette copy of your manuscript does not follow these conventions, it will be returned for correction.

We request diskette copies of figures also. While all the following formats are acceptable, the first 2 are preferred: PRE, PCX, EPS, TIF, GIF, BMP, and JPG. If the figures were not produced using computer graphics, or if conversion of graphics files to our desktop publishing software is unsuccessful, original, high-quality, scannable line drawings will be required.

GALLEY PROOF

The author has the ultimate responsibility for the content of the paper. Check the galley proof carefully. Clearly indicate corrections on the proof and return it to the Editors-in-Chief within 7 days of receipt.

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MANUSCRIPTS: Refer to the CBE Style Manual (6th Edition) and a recent issue of *California Fish and Game* for general guidance in preparing manuscripts. Specific guidelines are available in *California Fish and Game* 87(2):77-85.

COPY: Use good quality 215 x 280-mm paper. Double-space throughout with 25-mm margins. Do not hyphenate at the right margin or right-justify text. Authors should submit four good copies of their manuscript, including tables and figures, to the Co-Editors-in-Chief. An electronic copy of the manuscript on diskette in word processor format will be required with the final accepted version.

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FIGURES: Consider proportions of figures in relation to the usable page size of *California Fish and Game* (117 x 186 mm). Figures, including captions, cannot exceed this size. Figures and line-drawings should be clear, with well-defined lines and lettering. Lettering style should be the same throughout and large enough to be readable when reduced to finished size. Type figure captions on a separate page. High-quality photographs with strong contrast are acceptable and should be submitted on glossy paper. On the back and top of each figure or photograph, lightly write the figure number and senior author's last name. Be prepared to provide high-quality, scannable, original figures or graphics files on diskette with the final accepted manuscript.

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